6: Operational Amplifiers

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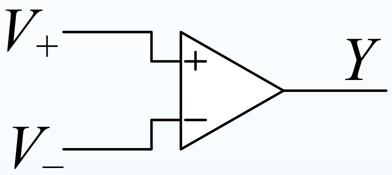

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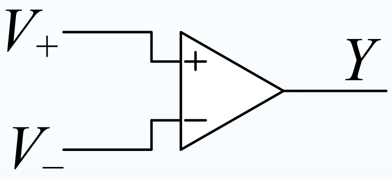

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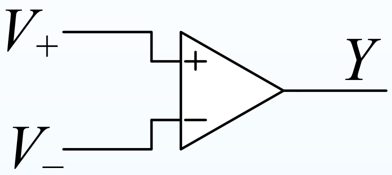

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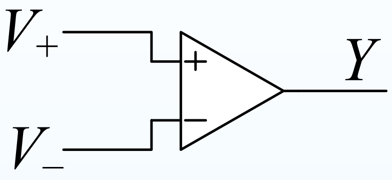

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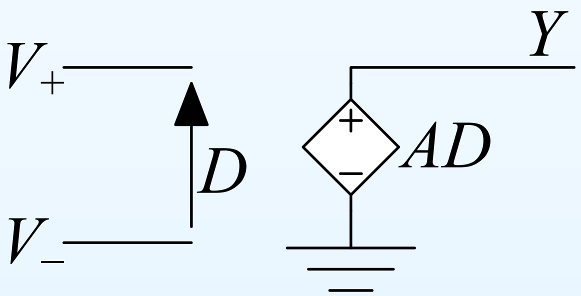

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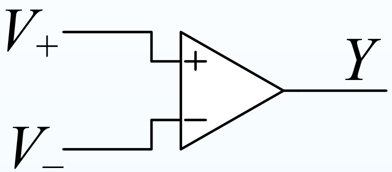

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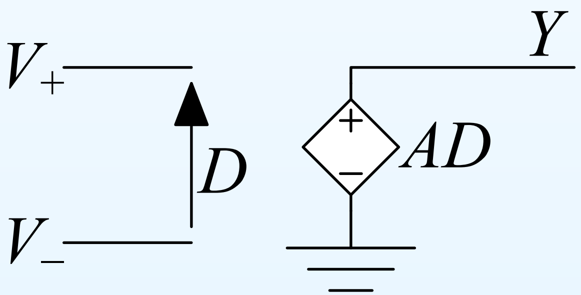
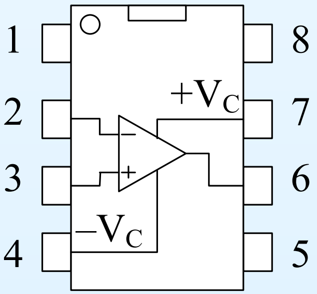


Integrated circuit pins are numbered anti-clockwise from blob or notch (when looking from above).



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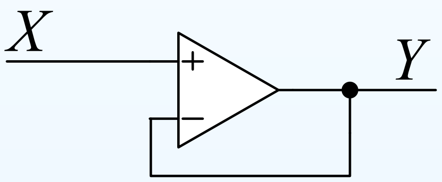

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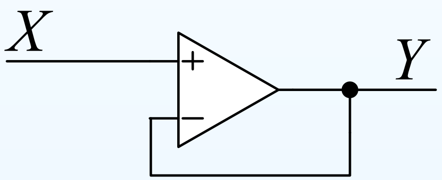

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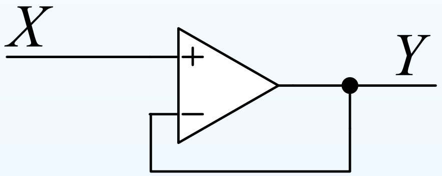

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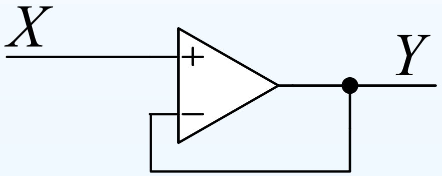

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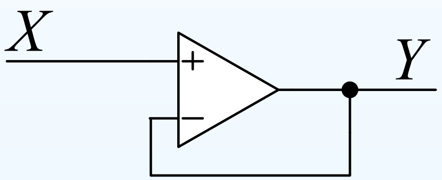

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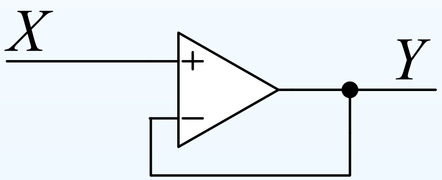

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Golden Rule: Negative feedback adjusts the output to make $V_+ \simeq V_-$.

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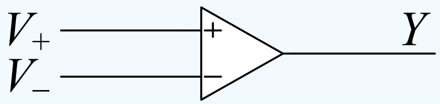
Nodal analysis is simplified by making some assumptions.



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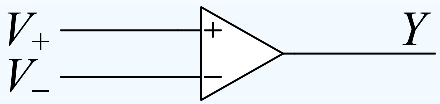

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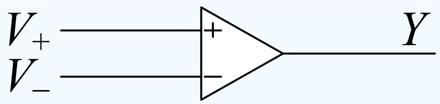

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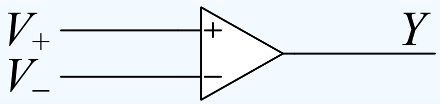

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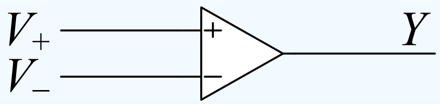

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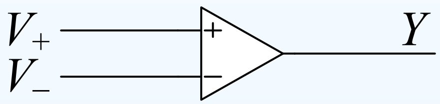

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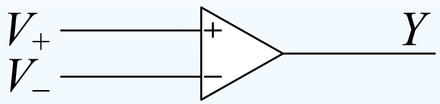

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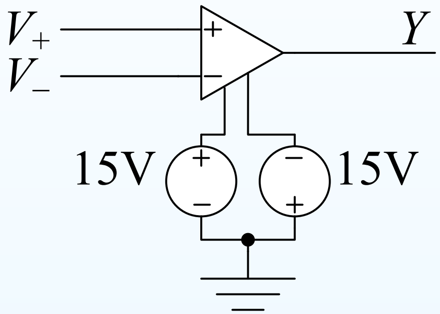

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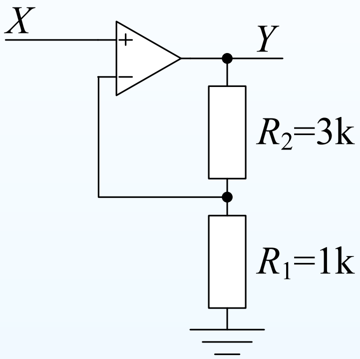

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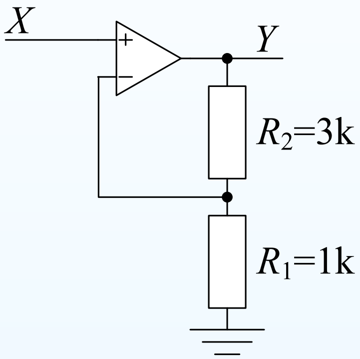

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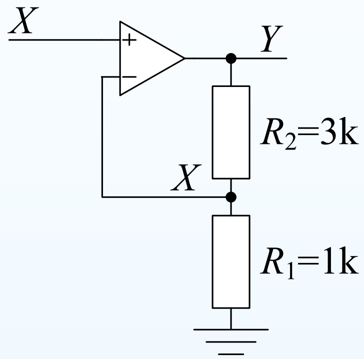

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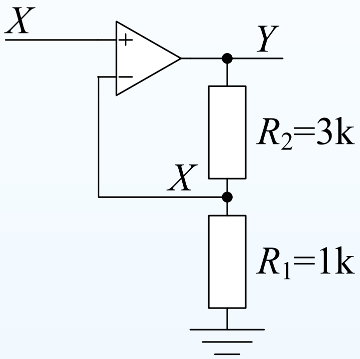

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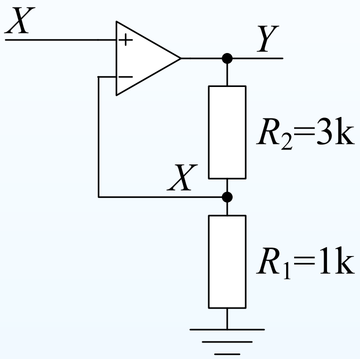

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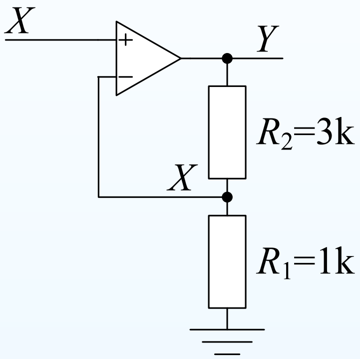

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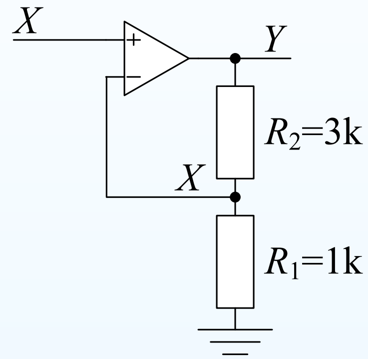

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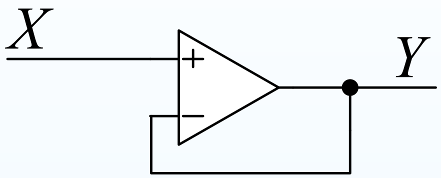
Cause/effect reversal: Potential divider causes $V_- = \frac{1}{4}Y$.
Feedback inverts this so that $Y = 4V_+$.

Voltage Follower

A special case of the non-inverting amplifier with $R_1 = \infty$ and/or $R_2 = 0$.



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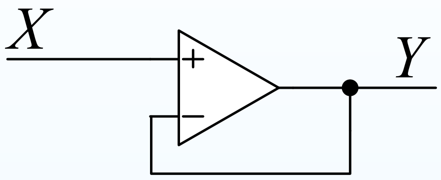

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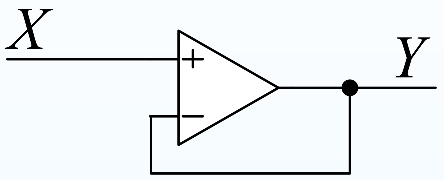

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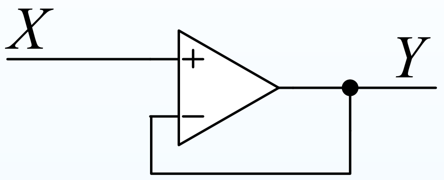

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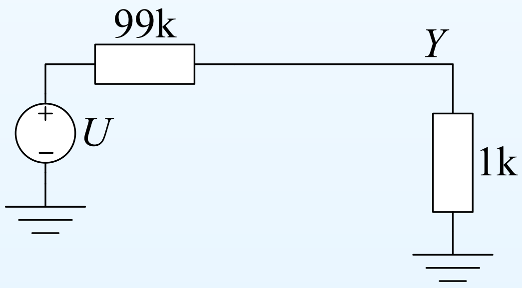

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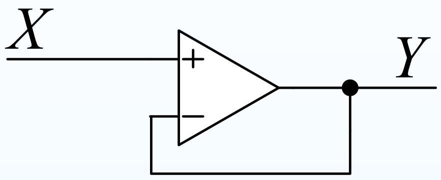

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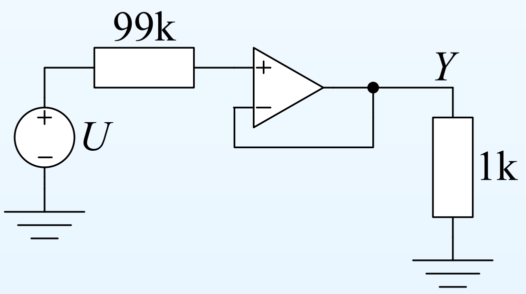

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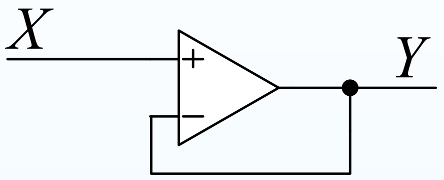

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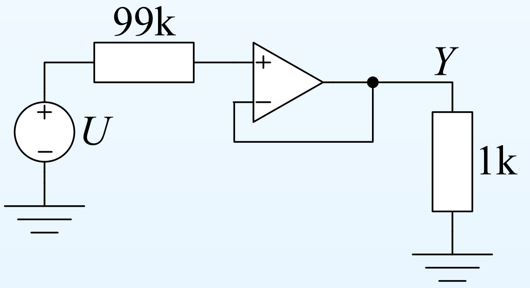
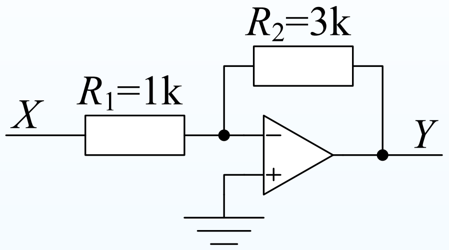


Although the *voltage gain* is only 1, the power gain is much larger.

Inverting Amplifier

Negative feedback OK.



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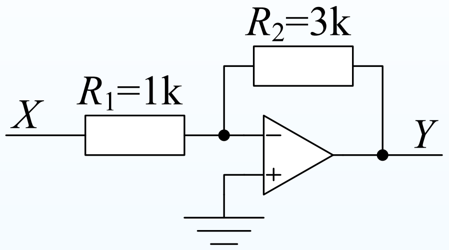

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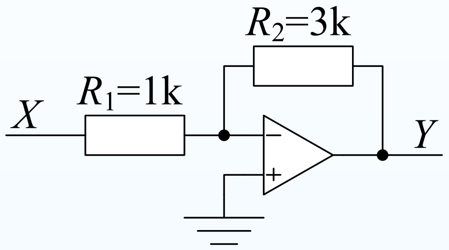

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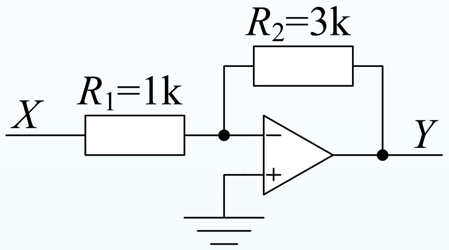

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Can have any gain ≤ 0 by choosing the ratio $\frac{R_2}{R_1}$.

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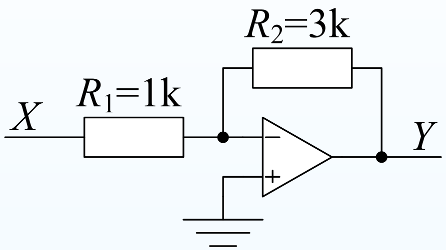

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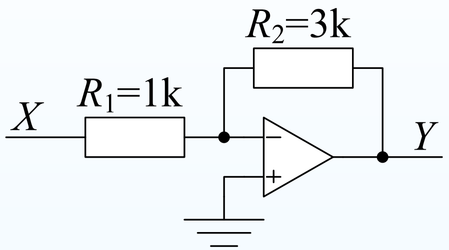

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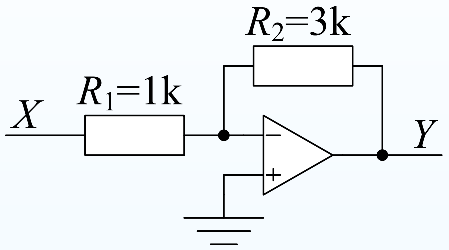

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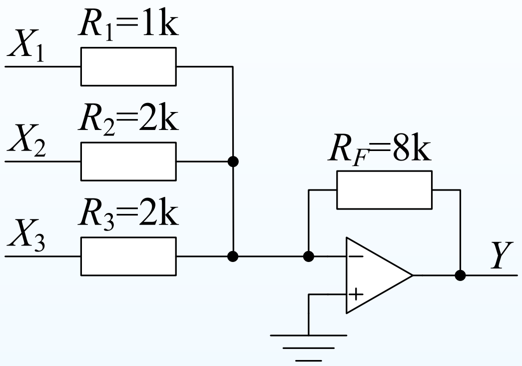
Inverting Summing Amplifier

We can connect several input signals to the inverting amplifier.



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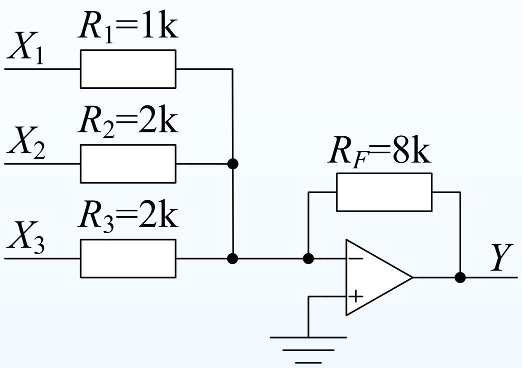

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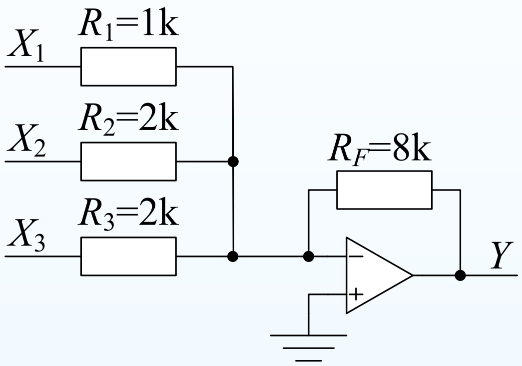

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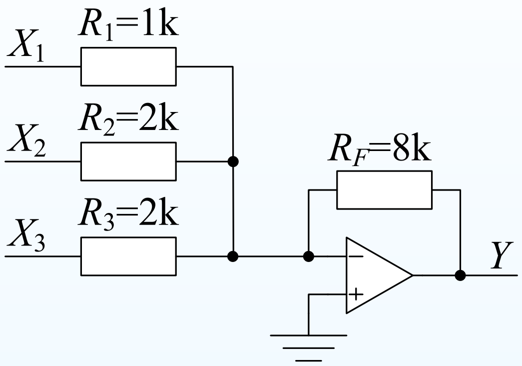

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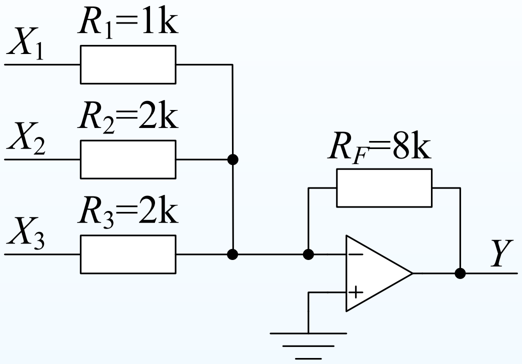

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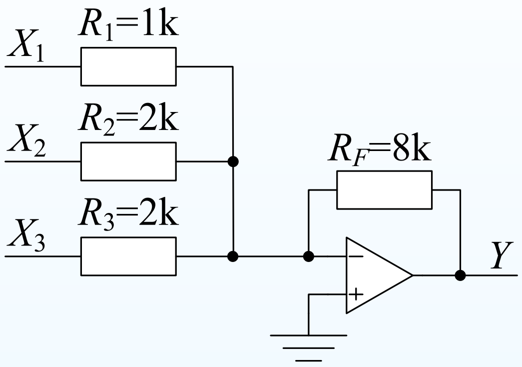

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Y is a weighted sum of the input voltages with the weight of X_i equal to $-\frac{R_F}{R_i} = -G_i R_F$.

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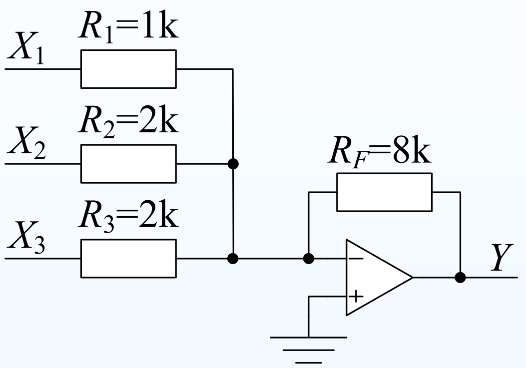

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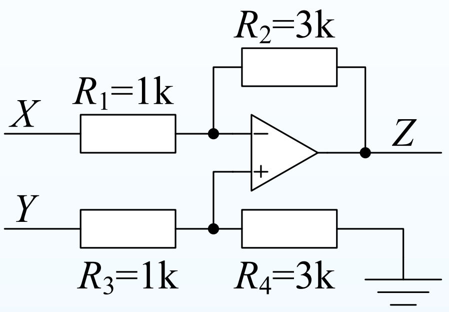
Input Isolation: The current through R_1 equals $\frac{X_1 - 0}{R_1}$ which is not affected by X_2 or X_3. Because V_- is held at a fixed voltage, the inputs are isolated from each other.

Differential Amplifier

A 2-input circuit combining inverting and non-inverting amplifiers.



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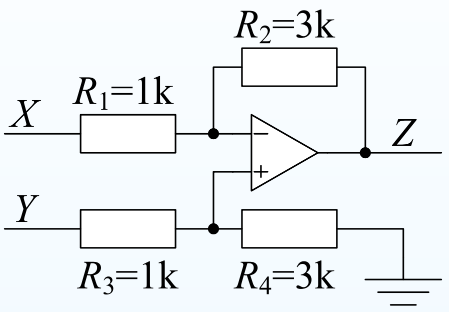
Use superposition to find a and b.



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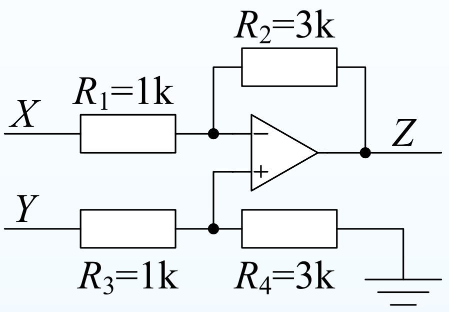

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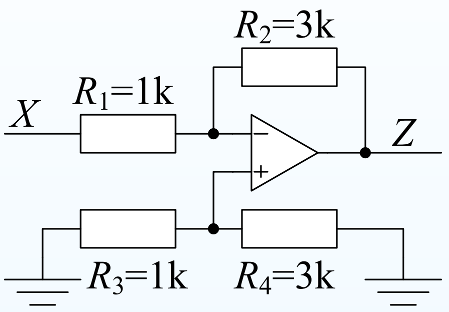

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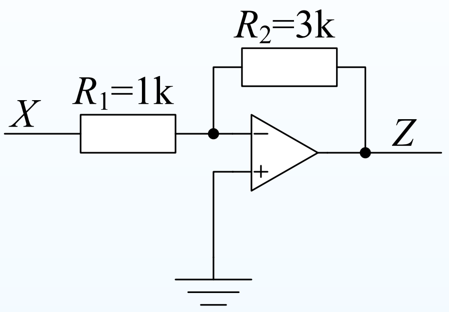

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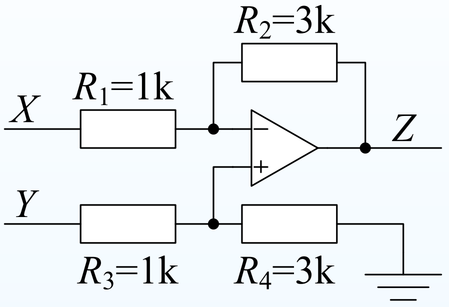

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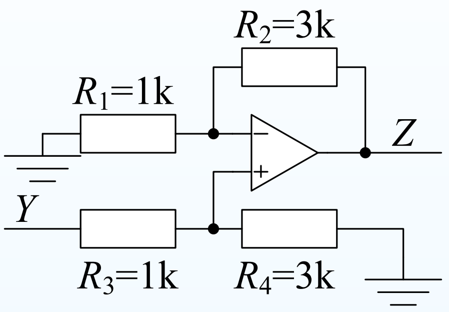

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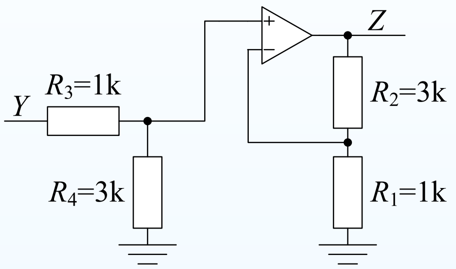

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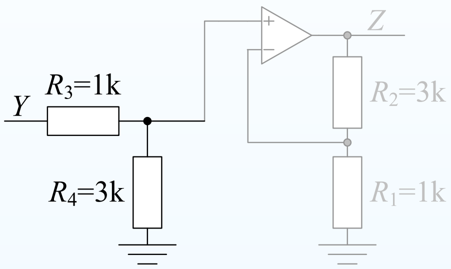

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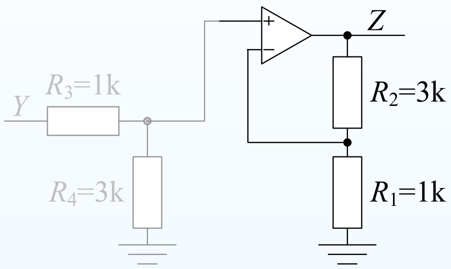

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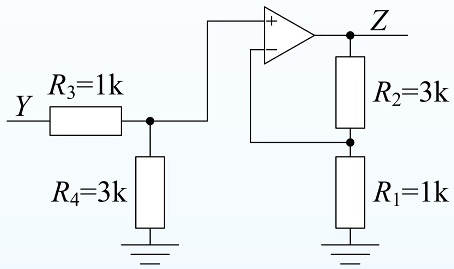

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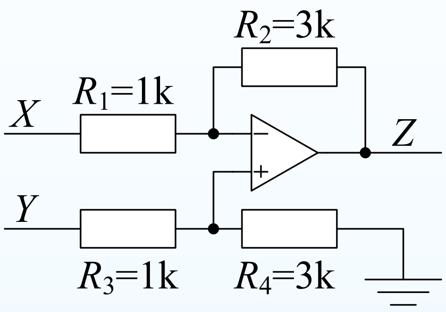

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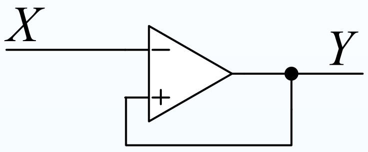
Combining the two gives $Z = 3\left(Y - X\right)$. The output of a *differential amplifier* is proportional to the diffference between its two inputs.

Schmitt Trigger

Positive feedback: If op-amp output Y *rises* then $(V_+ - V_-)$ will increase. This causes Y to *rise* even more up to its maximum value (e.g. $+14\,\mathrm{V}$).



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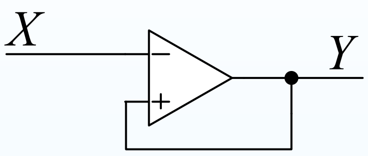

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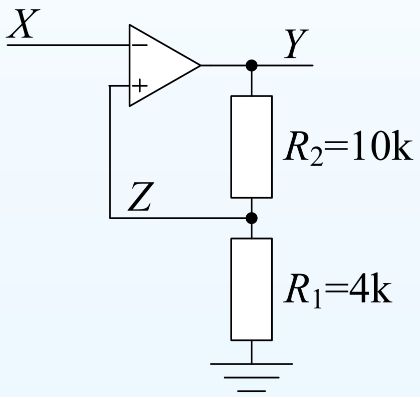

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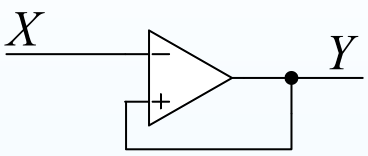

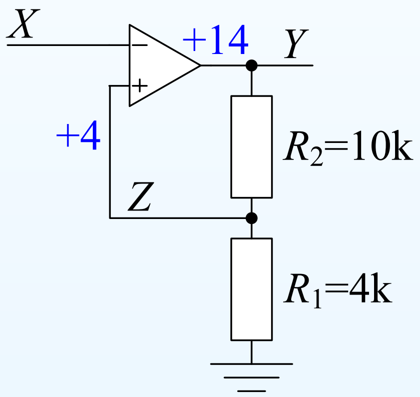

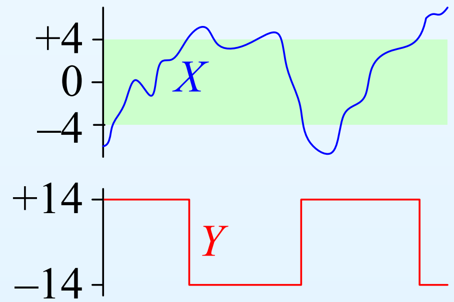

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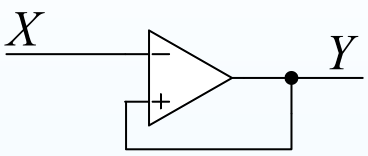

If $Y = +14\,\mathrm{V}$, then $Z = 4$. For any $X < 4$, $(V_+ - V_-) > 0$ so the output stays at $+14\,\mathrm{V}$.
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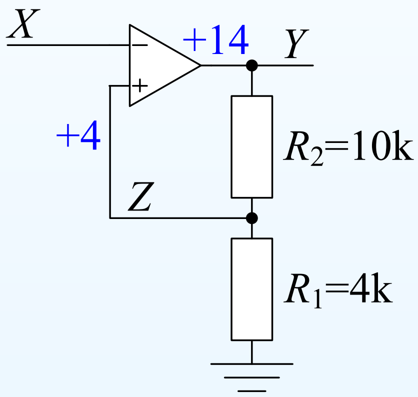

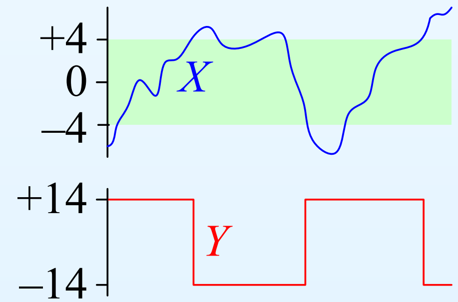

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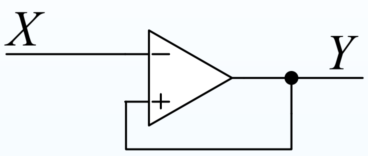

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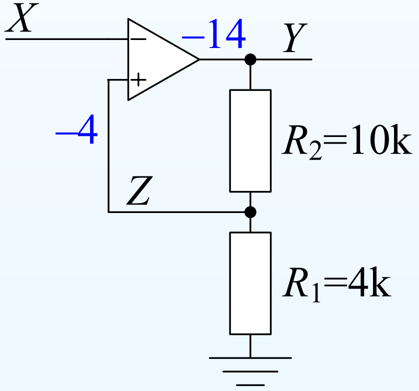

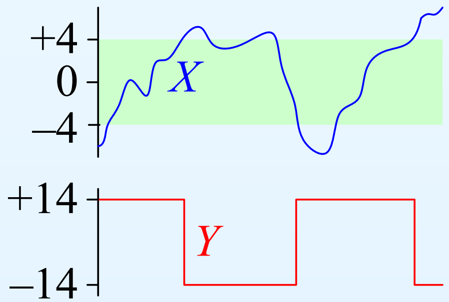

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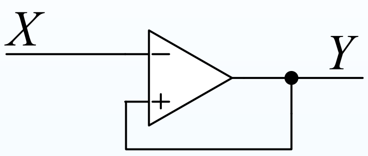

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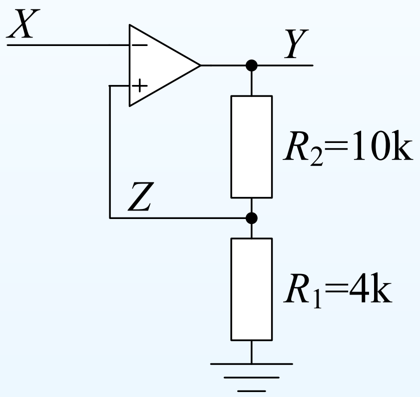

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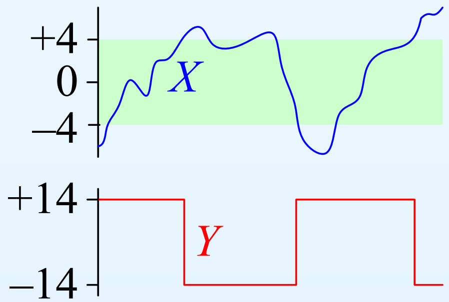

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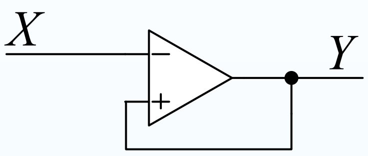

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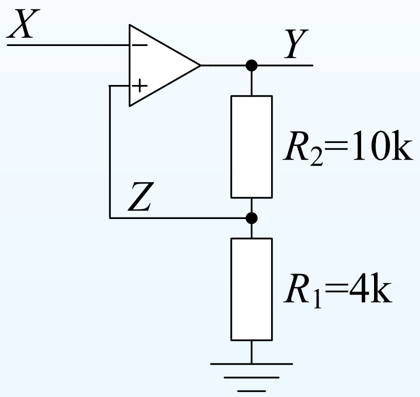

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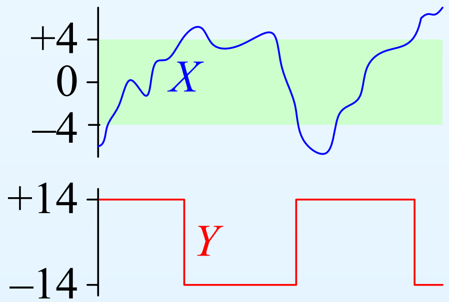

Switching will happen when $V_+ = V_-$.

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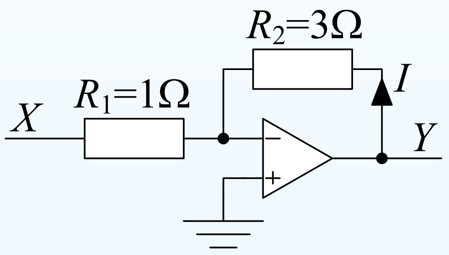

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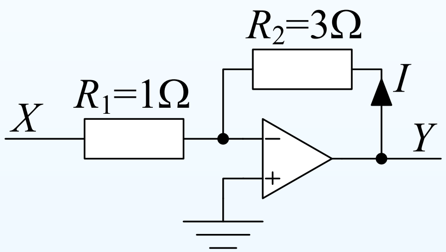

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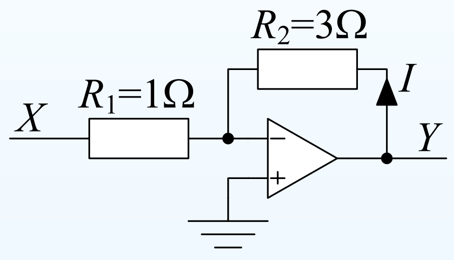

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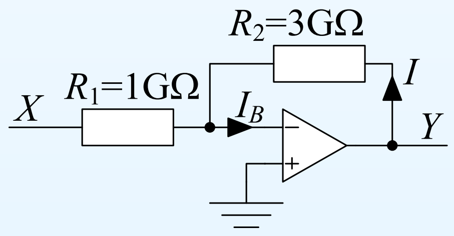

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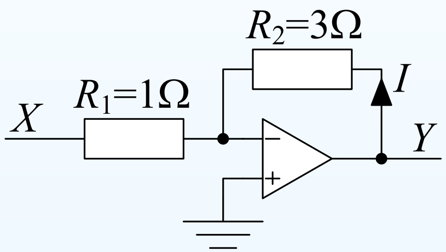

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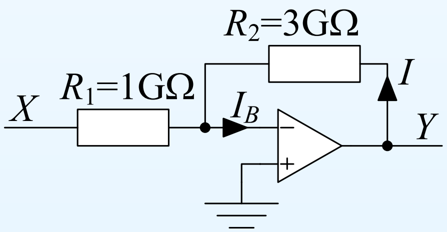

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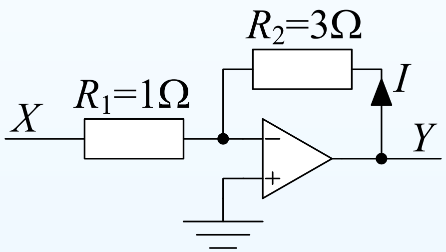

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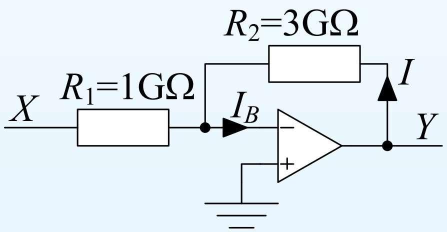

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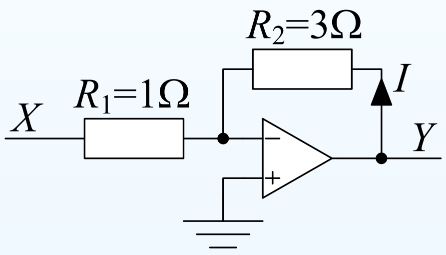

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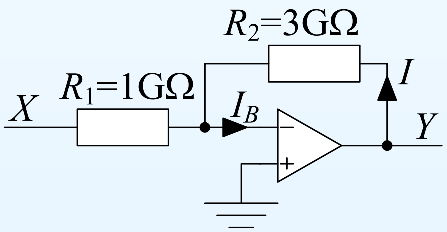

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Within wide limits, the absolute resistor values have little effect.
However you should avoid extremes.

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For further details see Hayt Ch 6 or Irwin Ch 4.